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Wine tasting based on emotional responses: An expedite approach to distinguish between warm and cool climate dry red wine styles

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ABSTRACT

In this study, we improved an empirical tasting sheet including emotional responses and common sensory attributes. An Optimized Descriptive Profile (ODP) was run to characterize different red wines according to sensory descriptors used in the improved sheet. A total of 5 wines were evaluated by a Consumer Panel (CP) of 103 subjects (36 females, 67 males) using the improved sheet and a Check-All-That-Apply (CATA) list of 25 emotions. In the ODP, the panel identified the main discriminating sensory attributes as "Complexity", "Astringency" and "Duration of the wine fragrance". However, this analysis did not allow for differentiating very distinct dry red wine styles originating from warmer or cooler regions. On the contrary, Principal Component Analysis of emotional attributes demonstrated that these two wine styles could be easily distinguished. In particular, wine with a red-brick color, complex smell and aggressive mouthfeel consistent with those from cooler regions was less liked by the CP than a warm climate gold-awarded wine. Although receiving lower scores considering its color and smell, the former wine was regarded as the most "surprising" in the CATA.

1. Introduction

Wine is a fascinating product that has been produced and praised for thousands of years in many parts of the world (This, Lacombe, & Thomas, 2006). One should think that with such history, profound cultural background, and linkage to so many civilizations there would be some common and spontaneous vocabulary on how to talk about wine. Wine sensory analysis has largely been developed to answer this need for describing and evaluating wines. The focus has been put on the ability of tasters to describe sensory attributes elicited by visual, olfactory and taste-mouthfeel sensations (Jackson, 2014). However, wine is not easy to describe, assess, or evaluate, and it is questioned if wine judging requires a particular degree of expertise (Hopfer & Heymann, 2014). In fact, human senses are not accurate measures of these sensations due to physiological or cognitive limitations (Lawless, 1999). Cognitively, the same descriptor can be attached to two different sensory perceptions or the same sensory perception with two different words, while cultural background is decisive for interpreting the semantics related to wine description (Bastian, Bruwer, & Alant, 2005; Paradis & Eeg-Olofsson, 2013; Sáenz-Navajas, Ballester, Pêcher, Peyron, & Valentin, 2013). As a result, conventional sensory analysis seems to create a communication gap between wine experts and consumers, and so new approaches to tackle this drawback are welcome (Francis & Williamson, 2015; Hopfer & Heymann, 2014). Moreover, considering that consumer preferences are not only driven by food intrinsic attributes (De Pelsmaeker, Schouteten, Lagast, Dewettinck, & Gellynck, 2017), these new approaches may be explored outside the field of conventional sensory analysis.

Ubigli (2004) observed "the sensory signal, in the strictest sense, is complemented by a multitude of other information of a hedonistic and emotional type," and perception is not just about a physiological reaction, but an "activity that involves knowledge and reflection". When triggered by food, emotions can have five different sources: sensory properties, experience, anticipated experience, personal or cultural significance, and third-party influence (Desmet & Schifferstein, 2008; Jiang, King, & Prinyawiwatkul, 2014; Meiselman, 2015). Mostly positive emotions have been used to differentiate between and within food categories (Jager et al., 2014; King, Meiselman, & Carr, 2013; Ng, Chaya, & Hort, 2013). In particular, Jiang et al. (2014) listed 78 positive, 55 negative and 23 neutral emotions. However, a balance between negative emotions was recommended by Meiselman (2015) in product development.

Using emotional attributes to describe wines was first reported by Ferrarini et al. (2010) and Rive and Deneulin (2014). In these works, the wine was not tasted and no attempt was made to relate emotions to sensory characteristics of wine. Hopefully, this relation would enable

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wine professionals to anticipate consumer preferences and better predict wine choice, which is a common challenge for food companies in the present competitive business climate (De Pelsmaeker et al., 2017; Kenney & Adhikari, 2016), and has been demonstrated with basic taste solutions (Samant, Chapko, & Seo, 2017) and in chocolate with different sweetness (Lagast, De Steur, Schouteten, & Gellynck, 2017; Thomson, Crocker, & Marketo, 2010). Having this concern in mind, Loureiro, Brasil, and Malfeito-Ferreira (2016) proposed a tasting sheet where the emotional responses were explained by the sensory characteristics of wines, enabling recognition of the so-called classic European wines mostly produced in cooler climate regions.

The present study was an extension of that and intended to explore the emotional reactions induced by dry red wines and see how these reactions can be used to describe and evaluate wine. While Loureiro et al. (2016) used an empirical tasting sheet to train two student tasting panels, our work was first directed to improve that sheet followed by testing it with a large consumer panel without previous training. Therefore, our objectives were: (i) to adapt an empirical wine tasting sheet to include emotional responses and conventional sensory attributes to be used by consumers to describe and evaluate wines; (ii) to evaluate the relevance of emotions in wine appreciation; and (iii) to differentiate between wines with different styles using emotional responses.

2. Materials and methods

The research was divided into three sensorial methodologies: Focus Group (FG), Optimized Descriptive Profile (ODP) and Consumer Panel, which can be visualized in Fig. 1. Participants were not compensated for their work.

2.1. Focus Group (FG)

2.1.1. Wine selection

The approach described by Loureiro et al. (2016) requires the use of two wines with clearly opposite styles. Therefore, Focus Groups tasted two red wines chosen from warm climate and cool climate regions. First, the example of a warm climate wine was a 2013 concentrated dark red wine with a high aromatic intensity (over-matured red fruits and noticeable oak) and a low acidity and short finish, which had been awarded a gold medal in an international challenge originating from Palmela DOC (Portugal). The second wine, typical of cool climates, was a 2004 Pommard Premier Cru (Burgundy), with a light red-orange color, discreet and complex aroma evolving over time, high acidity and long persistence.

2.1.2. Tasting panels

Participants were recruited through a questionnaire distributed among 50 students aiming at selecting those who consumed wine at least once a week. The first tasting panel consisted of two FGs organized among Instituto Superior de Agronomia (ISA) students ranging from 22 to 46 years old, all with different wine tasting knowledge. The first FG gathered 11 subjects (8 males and 3 females) regarded as experts given their background as students in their second year of the Master of Viticulture and Enology with extensive wine tasting training. The second FG gathered 10 non-experienced subjects (3 males and 7 females) in wine tasting, but with previous training in food sensory analysis being recruited from the Master's program in Gastronomical Sciences. Participants filled in a quick questionnaire with basic information on their socioeconomic profile and wine consumption habits.

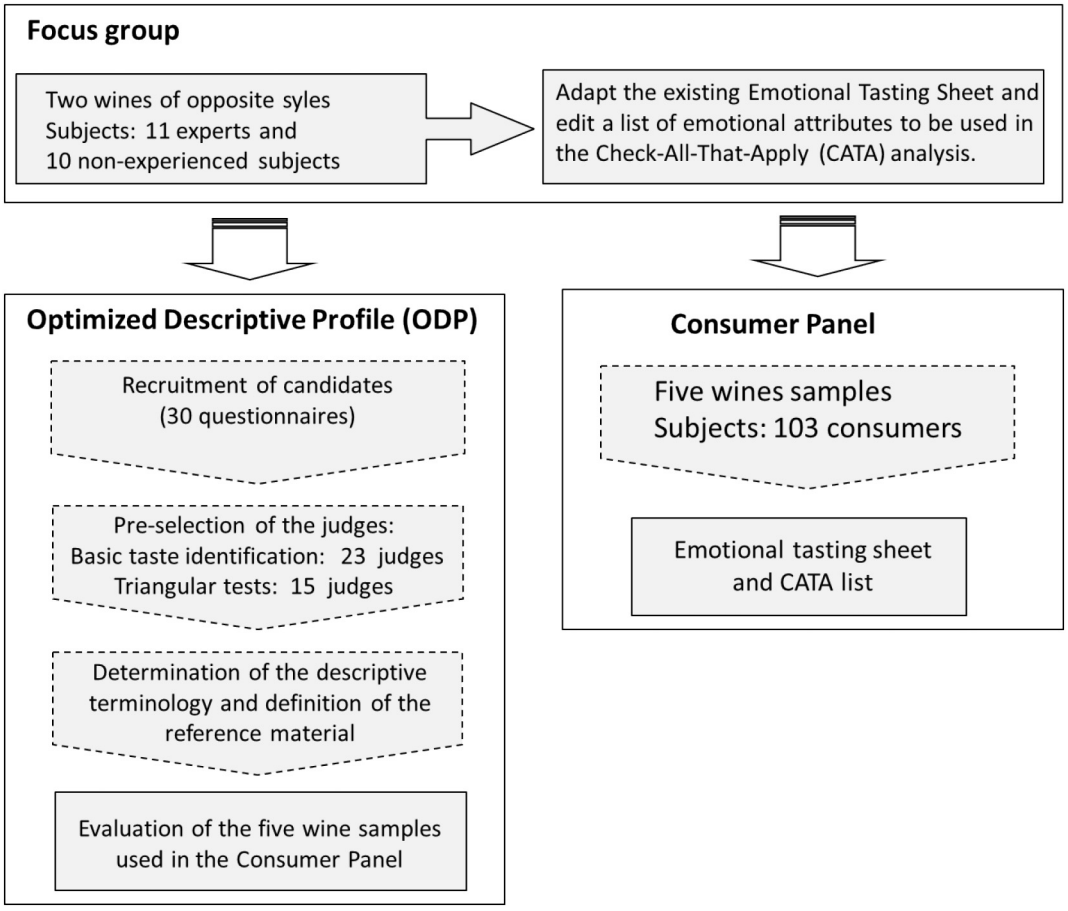

Fig. 1. Sensorial methodologies: Focus Group (FG), Optimized Descriptive Profile (ODP) and Consumer Panel.

2.1.3. Methodology

Focus group (FG) discussions were performed to adapt the existing emotional tasting sheet as described by Loureiro et al. (2016), and edit a list of emotional attributes to be used in the Check-All-That-Apply (CATA) analysis.

This work included two tasting panels with an average duration of 60 min for the FG sessions. The two Focus Group sessions took place in a 60 m^2 classroom with extensive natural light at ambient temperature (22–24 °C) without conditioned air flow. Tables were placed in a circle to allow maximum interactions between all the participants. Participants were asked to taste the wines and comment and discuss the emotional tasting sheet and the CATA list. When necessary, a mediator helped the group to focus their attention and discussion on the subjects described above. Notes were taken and a full transcription made from recording both sessions.

The base for our study was the emotional tasting sheet previously described by Loureiro et al. (2016), where emotional responses were included in the olfactory evaluation, the expectation for the mouth, impression in relation to odor, taste evaluation and overall taste evaluation.

In the CATA analysis, the list of emotional attributes was elaborated by merging two already existing lists recently described by Ferrarini et al. (2010) and Rive and Deneulin (2014). Both lists have been developed using self-reported questionnaires without wine tastings by the respondents. The synonyms or synonymous terms from both lists were eliminated, reaching a list of 37 terms as described by Silva et al. (2012).

2.2. Optimized Descriptive Profile (ODP)

2.2.1. Wine selection

A total of 5 red wines from Portugal were previously selected (Table 2) in order to feature the widest possible extent of sensations. The styles similar to warm climate wines were W2 and W3, where the former had a simpler smell without oak aging and less body; and the latter was a gold awarded wine, similar to the Palmela DOC tasted in the FG. Cool climate wine styles were selected in a region of mild temperatures and Atlantic influence, providing light color, discreet smell, and an astringent/sour mouthfeel (W4, W5), comparable to the style of 2004 Pommard tasted in the FG. W4 was a typical fine aged wine with evolved color and bouquet, astringency smoothened by bottle aging and a long finish. W1 was a blend of grapes originating from warm regions in the Douro river valley, and from cooler regions from higher altitude (500 m) vineyards of upper Douro, aimed at having an intermediate style between warm and cool climate wines.

The bottles were opened just before the tasting. Three replicate sessions were made to evaluate the judges and their consistency.

2.2.2. Methodology

2.2.2.1. Recruitment of evaluator candidates. Descriptive profile analysis is used to describe and quantify the sensorial proprieties of a product (Meilgaard, Carr, & Civille, 2006), and the procedure followed in this work was especially developed to be used with semi-trained subjects (Silva et al., 2012). Tasters were recruited from 30 ISA students who regularly consume wine on a daily or weekly basis, and were recruited face-to-face or by e-mail communication. Candidates first had to confirm they would be available and they had no health limitations. Then we tested the ability of all the judges to work with an unstructured scale (Meilgaard et al., 2006). All subjects were able to stay below the 10% accepted variation.

2.2.2.2. Pre-selection. A total of 23 panelists were selected by a basic taste identification in which they had to recognize the four different tastes (sweetness, acidity, saltiness, and bitterness) and pure water. Next, they were selected by means of a sequence of four triangular tests (acidity, sweetness, bitterness and astringency). Three (3) glasses were poured for each panelist served with 30 mL of solution, among which 2 were similar and one had a different concentration of the chemical responsible for said taste or sensation. Acidity and sweetness were tested on samples made from white wine, whereas bitterness and astringency were tested on samples made from red wine. 20 g/L of sugar were added to produce the sweetest sample; 1 g/L of tartaric acid was added to increase acidity; 20 mg/L of quinine sulfate was added to produce the bitterness; and finally, astringency was increased by adding 2 g/L of tannic acid. Participants with 70% level of confidence were select. A total of 15 judges were selected through this process (7 males and 8 females, which is a number considered enough to process the ODP by the method of Silva et al., 2012).

2.2.2.3. Determination of the descriptive terminology and definition of the reference material. The selected semi-trained judges evaluated wines on 8 different attributes over several sessions from April to May 2015, which consisted of several exercises, ordering tests, familiarization with the reference materials, and allocation of the intensity of the sensory attributes and a sample evaluation stage simulation by means of the ODP method. Each descriptor was defined as described by Loureiro et al. (2016) explained orally and there were two reference wines to illustrate the minimum and the maximum intensity of each one, prepared as described in Table 1. Dark ISO glasses were used for the reference wines to avoid color induced bias and wine order was randomized. A document listing all the attributes with their definition was given to each judge at each tasting session (Table 1).

2.2.2.4. Evaluation of the wines. The tastings were performed in a 100 m^2 classroom with dark benches where glasses were distributed on individual white paper mats with natural light at room temperature (22–24 °C) and without conditioned air. The room opened at 11:00 am and closed at 4:00 pm. All participants were given a short description for the main attributes to be evaluated (as described in Table 1) and the wines mentioned in Table 2.

Thus, the judges received all the samples at the same time and were asked to compare the products with the reference materials and indicate the intensity of the attribute for each sample on the unstructured scale. The bottles were refrigerated in order to be served at 16 °C. Three replicates were made in order to evaluate the judges and their consistency. A break of a few days was respected between each replicate. The presentation order was a balanced incomplete block design with carry-over control, using the algorithm of Hedderley & Wakeling (1995).

2.3. Consumer Panel

2.3.1. Tasting panel

All ISA students, professors, employees and visitors who reported that they consumed wine regularly were invited to join. Participants filled in a quick questionnaire with basic information on their socio-economic profile and wine consumption habits. The group of consumers (n = 103) consisted of 67 males and 36 females ranging from 18 to 66 years old with 26 years mean age, and 73% consumed wine daily or weekly. All consumers evaluated the wines the same day in ISA.

2.3.2. Wine selection

Participants were asked to evaluate the 5 wines previously used in the ODP (item 2.2.1).

2.3.3. Methodology

The tastings were performed in a 100 m^2 classroom with dark benches where glasses were distributed on individual white paper maths, with natural light, room temperature (22–24 °C) and without conditioned air. The room opened at 11.00 am and closed at 4.00 pm. The bottles were refrigerated in order to be served at 16 °C. After a short introduction about the study tasks, the consumers gave oral consent

Table 1
Descriptors and references used for the Optimized Descriptive Profile.

Descriptor	Definition and evaluation instructions[a]	Reference (extremes)
Olfactory evaluation		
Intensity	The taster measures the distance between the nose and the glass to evaluate the intensity: the closer the glass, the lower the intensity.	Minimum: 25% old white (Dão, Portugal), 42% 2012 white wine from ISA and 33% old sweet white wine (Portugal) (Wine A). Maximum: Muscat dry white wine (Palmela, Portugal, 2014) (Wine B).
Complexity	Difficulty in describing the smells, absence of dominant smell.	Minimum: Wine B. Maximum: Wine A.
Taste evaluation		
Thermal perception	Heat sensation in the mouth, stimulated by higher ethanol levels.	Minimum: Red wine 5 L Bag-in-Box (Portugal), with 1 g/L of tartaric acid (Wine C). Maximum: Wine C with 30 g/L sucrose and 60 ml/L ethanol (99.5% v/v).
Body	Sensation of fullness and richness in the mouth	Minimum: Wine C. Maximum: Wine C with 30 g/L sucrose and 20 mL/L glycerol.
Astringency	Complex sensation accompanied by shrinking, drawing or puckering of the skin or mucosal surface in the mouth.	Minimum: white wine from ISA 2012. Maximum: Wine C with 2 g/L of tannic acid.
Persistency	Time evaluation of the persistence of taste after the ingestion (or rejection); generally in relation to the acidity that increased the persistence.	Minimum: Wine C. Maximum: Wine C with 3 g/L of tartaric acid.
Final olfactory evaluation		
Evolution of the wine in the glass	Observation of any possible evolution in the aroma.	Minimum: Wine B Maximum: Wine A
Duration of the wine fragrance	The period during which wine odor is sensed.	Minimum: Wine B Maximum: Wine A

[a] All attributes and definitions were in reference and adapted from McMahon, Culver, and Ross (2017), ISO 5492 (2008).

Table 2
Summary description of the Portuguese red wines used in the Optimized Descriptive Profile and in the Consumer Panel.

Wine	W1	W2	W3	W4	W5
Denomination	DOC[a] Douro	IPR[b] Alentejano	DOC Palmela	IPR Beiras	DOC Bairrada
Vintage	2011	2014	2012	1999	2011
Visual	Intense red	Dark red, purple reflects	Dark red	Medium red, orange and brown	Intense red
Odor	Medium intensity	Medium intensity, red fruits, jammy	Intense, dark fruits, jammy, overoaked	Initially reduced, vegetal, red fruits	Low intensity, vegetal, red fruits
Acidity (taste)	Medium	Low	Low	High	High
Oak flavor	Medium	None	Intense	Slight	None
Residual sugars	< 2 g/l	< 2 g/l	< 2 g/l	< 2 g/l	< 2 g/l
Alcohol	14.5% vol.	13.5% vol.	14.5% vol.	13.5% vol.	13.5% vol.

[a] DOC: Portuguese acronym for Protected Designation of Origin.
[b] IPR: Portuguese acronym for Protected Geographical Indication.

Table 3
Values of $F_{sample \times taster}$ and significance levels for the sensory attributes of the red wines.

Attribute	$F_{sample \times taster}$	p-Value
Intensity (smell)	1.56	0.0180[a]
Thermal perception	1.30	0.1080
Body	1.23	0.1593
Astringency	1.37	0.0677
Persistency	1.15	0.2500
Evolution of the wine in the glass	1.95	0.0007[a]
Duration of the wine fragrance	1.90	0.0012[a]
Complexity	1.74	0.0045[a]

[a] Significant at 5% probability.

before they proceeded into the sensory analysis. All participants were given a short description for the main attributes to be evaluated (as described in Table 1) and the wines mentioned in Table 2 (the tasting method was the same as the one used for the ODP). The evaluation was done on paper ballots with the emotional tasting sheet (Table 3) and the CATA list which we had updated after the FG discussions. The participants were also asked to fill in the CATA list for what they would define as an "Ideal wine", according to the methodology described by Bruzzone et al. (2015). The presentation order was a balanced incomplete block design with carry-over control, using the algorithm of Hedderley & Wakeling (1995).

2.4. Statistical analysis

Analysis of Variance (ANOVA) and Principal Component Analysis (PCA) were used to analyze the results of the emotional tasting. In both the ODP and the Consumer Panel, the Tukey's honest significant difference (HSD) test was applied to all pairwise differences between means in order to detect significant differences between wine pairs.

The data from the CATA were analyzed with Cochran's Q Test to compare each combination of wine and attribute. A correspondence analysis was run to detect possible differences between the wines in their emotional profiles. Correlations between attributes were calculated to do a Principal Component Analysis to indicate possible relationships between attributes.

All analyses were performed with the software XLSTAT© (Addinsoft, 2016.3 Version). A p-value of 0.05 was considered for each statistical test unless stated otherwise.

3. Results

3.1. Focus Groups

Focus group discussions resulted in some modifications of the emotional tasting sheet and produced the emotions to be used in the CATA list. The tasting sheet was modified according to the propositions that were gathered during both Focus Groups, when unanimous. The main comments made by both groups are shown in Supplementary Material 1.

In the protocol described by Loureiro et al. (2016), a visual assessment is performed after smell and taste evaluations in order to reduce possible bias induced by wine color. However, both Focus Groups

in this work concluded that color should be evaluated first as it comes first to our senses. In order to decrease the influence of the color assessment on the rest of the evaluation (and also to keep it simpler), both "Appearance" and "Temporal condition" were removed. Instead of the color identification, the evaluation was given by a scale set from "Dislike (1) to Like (5)".

In the olfactory assessment, it was decided to eliminate the evaluation of "Elegance". The interpretation of elegance was very confusing for both experts and non-experts. It was therefore suggested to keep elegance (which can be an emotional descriptor for some) in the CATA list, but to delete it from the actual tasting sheet.

In the taste assessment, the evaluation of "Creaminess" was removed. It was indicated that creaminess was not appropriate when it comes to describing dry wines. Creaminess only caused confusion in the taste assessment, mainly among the experts. The mention of "Taste Perception" was added to the "Final Perception" sequence to ensure better understanding in the application field of "Final Perception".

In the "Final olfactory evaluation", the "Duration of the fragrance in the glass" was changed to "Duration of the wine fragrance" so as to prevent misunderstandings. Finally, the non-experts suggested that there should be an interspace between the main tasting sequences in order to insist on a separation and avoid any confusion. Fig. 2 shows the final material that was produced after completion and analysis of the focus group discussions and which was further used in the consumer panel.

3.1.1. List of attributes for the CATA

The CATA list was considered excessively long by both tasting groups. Too many choices were likely to discourage people from answering in a proper manner. It was agreed between participants that the list should not exceed 25 attributes. They proposed some eliminations based on similarity and were able to reach 25 emotions. For example "Disappointment" and "Unpleasantly surprised" were eliminated and replaced by "Disappointing". A few new contributions were also made such as "Relaxed" or "Chewable". The updated list is shown at the bottom of Fig. 2.

3.2. Optimized Descriptive Profile

In order to evaluate taster performance, the values of the interaction F (sample × taster) are listed in Table 3. Concerning the interaction sample × taster, we observed significant interaction for the attributes

Name:		Male/Female:	Age:	
TASTING SHEET				Wine number
Visual Evaluation				Score
Color		*Dislike (1) to Like (5)*		

Olfactory Evaluation (Nose)		
Initial Impression	*Distaste (1) to Attraction (5)*	
Intensity (Odor)	*Weak (1) to Strong (5)*	
Complexity	*Easy (1) to Difficult to describe (5)*	
Expectation for the mouth	*Low (1) to High (5)*	

Taste Evaluation (Mouth)			
Impression in relation to odor		*Disappointing (1) to Surprisingly good (5)*	
Taste Perception	*Thermal*	*Fresh (1) to Hot (5)*	
	Body	*Light (1) to Full-bodied (5)*	
	Astringency	*Smooth (1) to Rough (5)*	
Final Perception	*Persistency*	*Short (1) to Long (5)*	
	Overall	*Unpleasant (1) to Pleasant (5)*	

Final Olfactory Evaluation		
Evolution of the wine in the glass	*Unchanged (1) to Evolving (5)*	
Duration of the wine fragrance	*Short (1) to Long (5)*	

Global Evaluation	
Dislike a lot (1) Dislike a little (2) Do not like nor dislike (3) Like a little (4) Like a lot (5)	

CATA				
Pleasant ( )	Aggressive ( )	Joyful ( )	Passionate ( )	Desirable ( )
Daring ( )	Warm ( )	Chewable ( )	Disappointing ( )	Unpleasant ( )
Elegant ( )	Amusing ( )	Cloying ( )	Relaxed ( )	Overwhelming ( )
Euphoric ( )	Interesting ( )	Light ( )	Exhilarating ( )	Melancholic ( )
Peaceable ( )	Greedy ( )	Sensual ( )	Surprising ( )	Sickening ( )

Fig. 2. Final emotional tasting sheet and CATA list of attributes produced after the completion and analysis of the focus group discussions and that was further used in the consumer panel.

Table 4
Mean scores for each attribute in the Optimized Descriptive Profile.

Attributes	Wines					p-Value
	W1	W2	W3	W4	W5	
Intensity (smell)	3.611 a	3.462 a	4.249 a	4.509 a	3.264 a	0.069
Complexity	4.059 b	2.720 a	4.796 b	5.278 b	5.056 b	0.000
Thermal perception	4.662 a	4.040 a	4.769 a	4.671 a	4.600 a	0.548
Body	3.258 a	3.849 a	3.931 a	3.938 a	3.389 a	0.318
Astringency	5.733 b	4.307 a	5.240 ab	4.798 ab	5.587 b	0.014
Persistency	3.878 a	3.904 a	5.071 a	4.567 a	4.380 a	0.057
Evolution of the wine in the glass	3.956 a	3.273 a	3.713 a	4.331 a	3.687 a	0.332
Duration of the wine fragrance	4.058 ab	4.729 b	4.596 b	5.118 b	2.971 a	0.000

Note: Minimum: note 0; Maximum: note 9; numbers in the same row line followed by the same letter, or a pair of letters, are not statistically different ($p < 0.05$).

'intensity', 'evolution', 'duration of the fragrance' and 'complexity'. We did not observe significant interactions in the remaining attributes, indicating that there were no tasters scoring the wines contrarily to the whole panel. According to Stone and Sidel (2004), the interactions between samples and tasters may occur simply because some tasters use different parts of the scale to rate the intensity of an attribute and do not necessarily reflect training failure. An interaction effect is regarded as 'serious' when there is inversion in the perception of sensory stimuli. Moreover, for Cardello and Faria (1998) interactions are considered serious only when there are major disagreements among the tasters.

The results of the sensorial analysis run by the 15 judges over three repetitions are presented in Table 4. It shows the estimated mean scores for each attribute of non-emotional nature. There were no significant differences between the wines in terms of "Intensity", "Thermal", "Body", "Persistency" and "Evolution of the wine in the glass".

Differences among the wines were found in the descriptors "Complexity", "Astringency" and "Duration of the wine fragrance". Wines W1, W3, W4 and W5 had a higher "Complexity", whereas wine W2 had very low complexity, as expected from our empirical wine selection. Wines W1 and W5 were considered more astringent, and W2 less astringent. W3 and W4 had intermediate astringency. Finally, wines W2, W3 and W4 had a long "Duration of the wine fragrance", but wine W5 had a very short one.

The observation of the little overall differences in the attributes justified running a Principal Component Analysis (PCA). In fact, it was possible to obtain clear discrimination between the wines. The first two eigenvalues corresponded to > 80% variance which ensured good quality of the projection on a two-axis map, as shown in Fig. 3. The variability between the wines explained by component 1 was mainly due to "Intensity", "Persistency", "Evolution of the wine in the glass", "Complexity" and "Thermal". The variability explained by component 2 mainly came from "Fragrance", in opposition to "Astringency".

Regarding the wines, W2 was isolated from the others and on the opposite side of the plan regarding attribute localization. Indeed, W2 was the wine that tended to receive the lowest scores for most factors. On the contrary, W3 and W4 were grouped and close to most attributes as a result of higher scores. Finally, W5 and W1 were also grouped, but not on the same side as the factors. Overall, W2 was clearly discriminated from all the other wines.

3.3. Consumer Panel

3.3.1. Correlations between the descriptors (Pearson correlation)

We first looked at the possible correlations between the variables evaluated in the emotional tasting sheet. The main correlations were all for emotional attributes. No significant negative correlations were found, while two relatively high positive correlations were detected. The first between the "Overall taste evaluation" and "Overall evaluation" ($r = 0.796$, $p \leq 0.05$) could be explained by the major influence of taste on the final assessment of the wine. Indeed, it would have been rather surprising to have no correlation or negative correlation between those two major evaluations in the tasting sequence. Another significant correlation between the "Initial impression" and the "Expectation for the mouth" ($r = 0.787$, $p \leq 0.05$) showed that the first impression did not seem to be altered that much during the actual olfactory assessment while evaluating "Intensity" and "Complexity". The "Initial impression" was somehow confirmed, and reflected in the expectations the taster had for the taste evaluation.

Next, we found two other interesting correlations, although a bit weaker, but yet above 0.600. They were between the "Impression in relation to odor" and "Overall taste evaluation" ($r = 0.683$, $p \leq 0.05$) or "Overall evaluation" ($r = 0.639$, $p \leq 0.05$), meaning that the surprising impression in relation to odor was reflected in higher overall taste and overall evaluations. Moreover, these correlations were higher than the correlations obtained from the smell evaluation ("initial Impression", "Expectation for the mouth") and the taste and overall evaluations. This result suggests that the taste sensation seems to be more important than the olfactory sensation in the overall evaluation of red wine. It remains to be seen if this observation derives from the choice of an attribute that explores the surprise effect after wine ingestion.

3.3.2. Discriminating descriptors and overall scores

The results listed in Table 5 show the descriptors that were most discriminating (p-value < 0.01) when applying the emotional tasting sheet. Three (3) descriptors having the most important discriminating powers are in the order they appear in the tasting sheet: "Color", "Initial impression" and "Expectation for the mouth". These 3 descriptors are of an emotional nature, ranging from negative to positive emotions equivalent to those listed by Jiang et al. (2014). In particular, "Color" was assessed from disgust/dislike to good/like, "Initial impression" revealed different levels of disgust/distaste to desire/attraction, and "Expectation for the mouth" was rated from low to high equivalent to different levels of interest. The 4th descriptor ("Overall evaluation") can also be considered as an emotional feature because the overall evaluation is rated between "dislike a lot" and "like a lot". This conclusion must be nuanced as the coefficients of determination (R^2) for each attribute were quite low, with the highest being 0.224 for "Color" (results not shown). This means that only a small part of the variability can be explained by these variables.

The scores for each of the attributes of the emotion based tasting sheet are shown in Table 5 and the frequency in Supplementary Material 2. The highest score was given to W1 and the lowest to W4, but there were no differences among W1 and W2, W3 and W5, or among W4 and W2, W3 and W4. The score of W4 is understandable, as it was chosen as an example of the cool climate classic European red wines, 16 years old and an obvious red-brown color with aging bouquet. This color was not appreciated given that it received the lowest scores. This low appreciation changed when subjects tasted the wine. W4 was the only wine where the score for "Impression in relation to odor" was higher than the score given for the "Expectation for the mouth" among all wines, revealing that mouthfeel was better than expected. Moreover, W4 showed no differences ($p < 0.05$) with at least one of the other wines for the remaining descriptors. Interestingly, the quality perception of W4 seemed to have improved during the tasting sequence. Its scores relatively increased the most during the tasting process. Although its color and odor made a weak impression, it was not differentiated when tasted ("Overall taste evaluation") and had an "Overall evaluation" that was not significantly different from the other 3 wines (W2, W3 and W5).

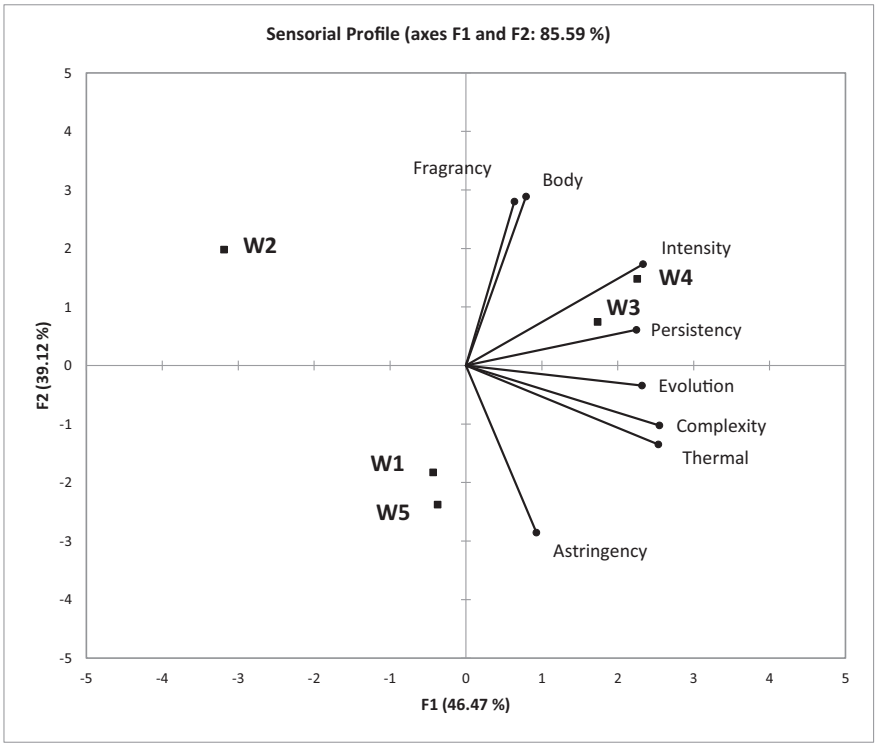

Fig. 3. Two-dimensional map made from PCA of the sensorial profiles of the red wines by Optimized Descriptive Profile.

3.3.3. Wine differentiation by PCA

Wine discrimination given by Principal Component Analysis (PCA) applied to the descriptor scores was explained by only two axis (> 90%). All vectors went in the same direction along the F1 axis, but seemed to split into two groups along the F2 axis (Fig. 4). A first group made of "Initial impression", "Color" and "Expectation for the mouth" were on the same side with "Overall taste evaluation" and "Overall evaluation", all of the emotional nature. The second group of attributes composed of a sensory nature (such as "Duration of the wine fragrance", "Body" and "Thermal perception") were in the upper right quadrant. The 5 descriptors with lower discriminating power were not plotted in the PCA plot. The gold awarded wine (W3) and W1 were placed close in the plan reflecting their similar sensory features. W5 was the closest to the centre of the plot, reflecting an average sensory pattern among all wines. The wine considered as simpler (W2) was distant from all the others and in the left low quadrant in opposition to W4 in the high left quadrant. In summary, the position of the 5 wines was more consistent to their overall sensory features than the respective positions provided by the ODP (see Fig. 3). The most relevant output was the different position of W3 and W4, reflecting the influence of emotional descriptors on the discrimination of wines clearly different in their sensory features.

3.3.4. Emotion analysis by Check-All-That-Apply (CATA)

3.3.4.1. Differences between the wines. In CATA, Cochran's Q Test was used to independently compare the wines for each attribute (Table 6). Independence between the rows and columns was tested using the Chi-square distance (results not shown). The resulting p-value was well lower than the significance level (0.05), and allowed us to conclude that the results given for the 5 wines were actually showing significant differences.

Only 6 out of the 25 emotions were associated to significant p-values (< 0.05): "Pleasant", "Cloying", "Surprising", "Relaxed", "Interesting" and "Desirable". It means that at least one pair of wines

Table 5
Estimated mean values of each attribute of the tasting sheet for wines W1 to W5 by the consumer panel.

Descriptors	p-Values	Wines				
		W1	W2	W3	W4	W5
Color	0.000	4.030 c	3.612 b	3.912 bc	2.612 a	3.786 bc
Initial impression	0.000	3.480 b	3.379 b	3.520 b	2.767 a	3.350 b
Intensity (smell)	0.150	3.265 a	3.301 a	3.369 a	3.126 a	3.068 a
Complexity	0.295	3.353 a	3.157 a	3.272 a	3.126 a	3.097 a
Expectation for the mouth	0.001	3.461 b	3.184 ab	3.422 b	2.864 a	3.294 ab
Impression in relation to odor	0.427	3.317 a	3.087 a	3.204 a	3.090 a	3.108 a
Thermal perception	0.014	3.157 b	2.743 a	3.194 b	3.039 ab	2.951 ab
Body	0.011	3.178 b	2.709 a	3.059 ab	3.049 ab	3.020 ab
Astringency	0.316	3.353 a	3.137 a	3.291 a	3.282 a	3.437 a
Persistency	0.010	3.461 ab	3.087 a	3.569 b	3.311 ab	3.272 ab
Overall taste evaluation	0.016	3.529 b	3.235 ab	3.324 ab	3.147 a	3.107 a
Evolution of the wine in the glass	0.259	2.843 a	2.660 a	2.864 a	2.624 a	2.854 a
Duration of the wine fragrance	0.072	3.200 a	2.961 a	3.311 a	3.225 a	3.099 a
Overall evaluation	0.007	3.738 b	3.379 ab	3.524 ab	3.136 a	3.417 ab

Note: numbers in the same row line followed by the same letter, or a pair of letters, are not statistically different ($p \leq 0.05$).

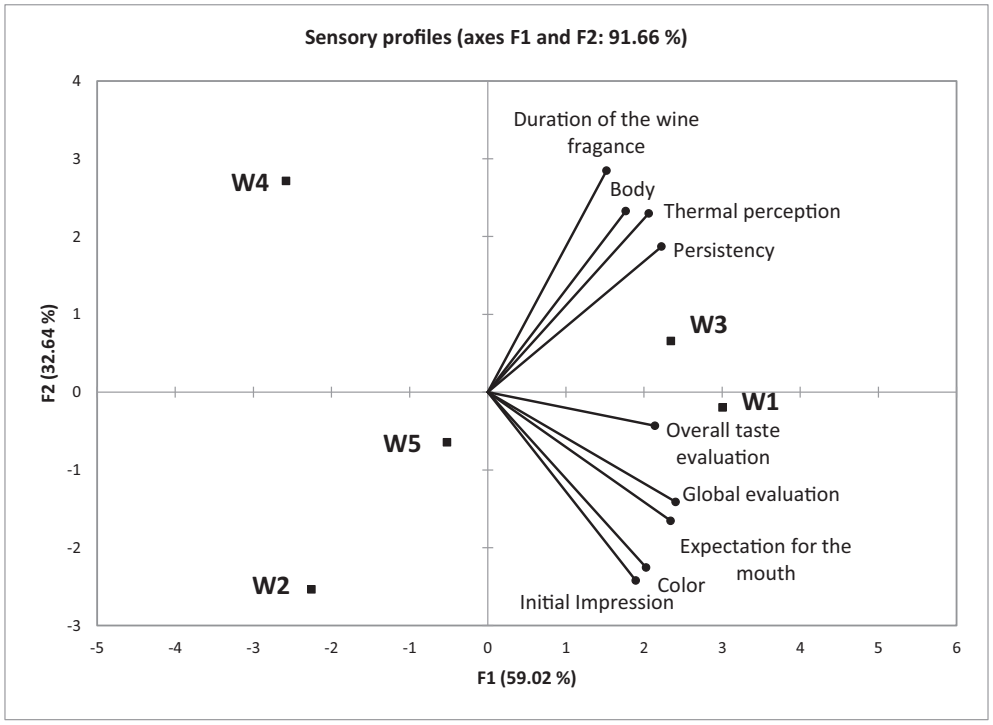

Fig. 4. Two-dimensional map made from PCA of the wine descriptor scores using the emotional tasting sheet by consumer panel.

Table 6
Cochran's Q test for each emotion of the CATA list.

Attributes	p-Values	Wines				
		W1	W2	W3	W4	W5
Pleasant	0.000	0.388 ab	0.311 ab	0.476 b	0.214 a	0.282 a
Cloying	0.006	0.126 ab	0.194 ab	0.165 ab	0.233 b	0.058 a
Surprising	0.021	0.097 a	0.097 a	0.107 ab	0.223 b	0.117 ab
Relaxed	0.036	0.243 ab	0.252 b	0.184 ab	0.097 a	0.194 ab
Interesting	0.037	0.291 ab	0.136 a	0.311 b	0.262 ab	0.252 ab
Desirable	0.039	0.243 ab	0.194 ab	0.311 b	0.146 a	0.243 ab
Euphoric	0.054	0.078 ab	0.097 ab	0.029 a	0.136 b	0.068 ab
Aggressive	0.055	0.146 a	0.204 a	0.262 a	0.272 a	0.301 a
Unpleasant	0.087	0.097 a	0.087 a	0.078 a	0.184 a	0.126 a
Warm	0.087	0.340 a	0.184 a	0.291 a	0.282 a	0.252 a
Light	0.109	0.223 a	0.282 a	0.165 a	0.155 a	0.165 a
Greedy	0.110	0.068 a	0.126 a	0.078 a	0.068 a	0.029 a
Elegant	0.143	0.214 a	0.117 a	0.223 a	0.136 a	0.175 a
Joyful	0.178	0.126 a	0.184 a	0.097 a	0.078 a	0.126 a
Exhilarating	0.257	0.097 a	0.078 a	0.126 a	0.068 a	0.049 a
Sensual	0.264	0.107 a	0.049 a	0.117 a	0.087 a	0.058 a
Amusing	0.269	0.097 a	0.165 a	0.126 a	0.078 a	0.097 a
Sickening	0.317	0.058 a	0.039 a	0.097 a	0.058 a	0.097 a
Chewable	0.336	0.146 a	0.087 a	0.126 a	0.126 a	0.184 a
Passionate	0.338	0.058 a	0.097 a	0.107 a	0.068 a	0.049 a
Daring	0.347	0.194 a	0.107 a	0.136 a	0.184 a	0.155 a
Disappointing	0.556	0.097 a	0.165 a	0.126 a	0.165 a	0.146 a
Peaceable	0.644	0.146 a	0.126 a	0.165 a	0.097 a	0.155 a
Melancholic	0.654	0.078 a	0.117 a	0.068 a	0.117 a	0.097 a
Overwhelming	0.946	0.049 a	0.049 a	0.068 a	0.058 a	0.068 a

Note: numbers in the same row line followed by the same letter, or a pair of letters, are not statistically different ($p < 0.05$).

were significantly different from each other. Interestingly, “Euphoric” had a p-value = 0.054, but it was the last emotion where significant differences could be found among wines. All other emotions elicited the same level of responses for all wines. The “Euphoric” score was higher for W4 when compared to W3, although W3 had higher values for “Pleasant” and “Desirable”. In fact, W4 showed high scores not only for “Euphoric” but also for the “Surprising” attribute. Overall, W4 received scores for negative emotions equal to those given to the other wines (e.g. “Aggressive”, “Unpleasant”, “Sickening”).

3.3.4.2. Correlations matrix and principal component analysis. A few negative correlations were found between emotional attributes and no clear positive correlations were observed among the emotions of the CATA. Most correlations were quite obvious (between “Pleasant” and “Unpleasant”, or between “Light” and “Overwhelming”) and revealed two groups of emotions; one group made of emotions that bring a positive evaluation of the wine, and another one that has a negative impact (Fig. 5).

“Pleasant” and “Unpleasant” showed the highest correlations (r) between attributes and the “Overall evaluation” of the wines with 0.48 and − 0.50, respectively. No other correlations were found between the “Overall evaluation” and the emotions from the CATA. Principal Component Analysis (PCA) was applied to the correlation coefficients further on, and the results may be visualized in a two dimensional map (Fig. 6). This map helps to visualize how the Overall evaluations found in the CP were correlated to the attributes in the CATA.

Fig. 6 shows that the overall evaluation was associated with positive attributes like “Pleasant”, “Desirable and “Interesting”.

4. Discussion

In conventional tasting education the focus is put on sensory description, and so it is understandable that the recognition of high quality wines with an aging bouquet would require extensive practice to recognize their complexity and subtlety. However, current knowledge on sensory science has shown that experts cannot detect more than three or four different fragrances in complex odor mixtures (Jinks & Laing, 2001; Livermore & Laing, 1998). There may be disagreement even among professionals in assessing complex wines, where descriptors like “undergrowth” are regarded as indicators of high quality by some (Picard, Tempere, Revel, & Marchand, 2015), and as a fault by others (Sáenz-Navajas, González-Hernández, Campo, & Fernández-Zurbano, & Ferreira, V., 2012). Additionally, language has a disruptive effect on the sensory ability. In other words, trying to remember the name of a smell can actually inhibit the perceptual ability to detect it (Herz, 2000; Lorig, 1999). In addition, current training methods should

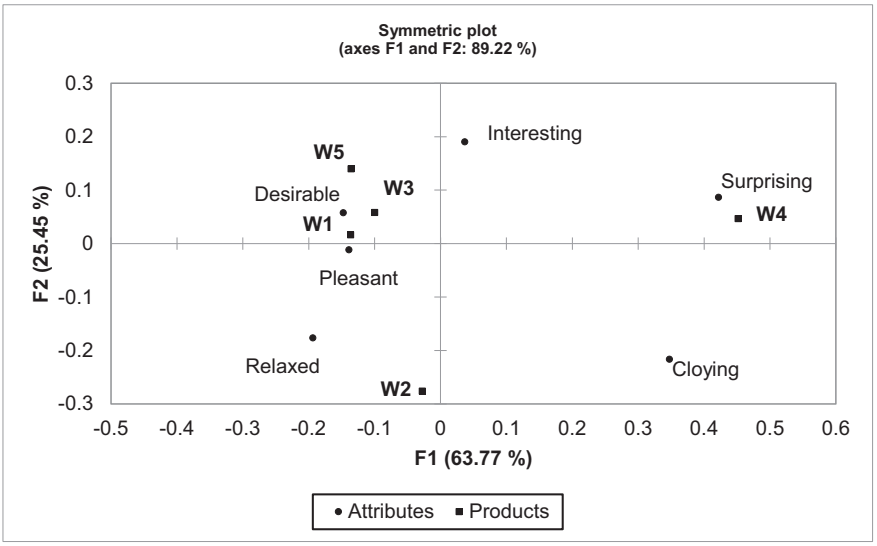

Fig. 5. Two-dimensional map made from PCA of the CATA emotional profiles of the wines by consumer panel.

refrain from emphasizing linguistic skills in the absence of well-developed relevant perceptional skills (Parr, Heatherbell, & White, 2002). All these issues cast some doubts on the use of the extensive lexicon created by experts (Cicchetti & Cicchetti, 2009; Langlois, Dacremont, Peyron, & Valentin, 2011; Noble et al., 1984) when it comes to communicating the qualities of a wine to consumers. Taste and mouthfeel sensations are less diverse than smells, but are also subjected to the same individual and semantic limitations. Taste perception is dependent on individual phenotypes (Hayes & Pickering, 2012), therefore eliciting different reactions to the same taste intensity. Texture properties like astringency are difficult to describe even among trained subjects (Sáenz-Navajas et al., 2016). Moreover, we have empirically observed that extensive lists of flavors and mouthfeel sensations bring disillusion to consumers who do not easily recognize those present in a particular wine. Thus, in our opinion the development of sensory description skills is only justified for training professionals, and is counter-productive for consumers.

The results presented in this work demonstrate that the selection of certain emotional responses elicited by wine might (Table 5) be used to differentiate between wine styles broadly defined as typical of warm and cool climate regions (Figs. 4 and 5). This approach performed better than the conventional description performed in the ODP with wines W3 and W4. In fact, W3 was a gold awarded dark red wine with a smooth mouthfeel, while W4 was an old red-brick wine with a sour and long finish. These two wines, despite their clearly opposite styles, were considered similar according to the PCA provided by the ODP (Fig. 3), but were clearly distinguished by the PCA of emotional attributes (Fig. 4).

The novelty of this approach stands in the relation between emotional reactions and wine sensory characteristics. In fact, using emotions elicited by foods has predominantly been directed to understanding enjoyment and purchase motivations, being mostly associated with positive reactions (Desmet & Schifferstein, 2008; Jager et al., 2014). On the contrary, we explored disapproval responses associated with certain wine styles to contrast with others that are, at first glance, more attractive. Despite receiving lower scores regarding its color and

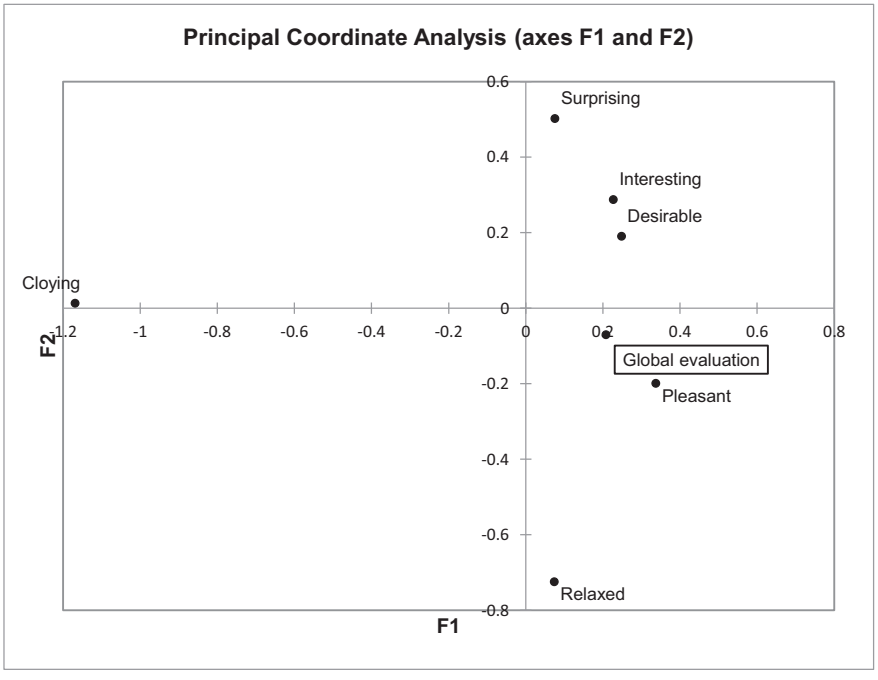

Fig. 6. Principal Component Analysis of the results from the CATA combined with the overall evaluation scores.

smell, the unattractive styles produced responses of positive "surprise" after drinking, which we propose should be explored as the key factor to rapidly characterize red wines with sensory features consistent with those from cool climate regions. This "surprise" might also be linked to the anticipated emotions, as recently discussed by De Pelsmaeker et al. (2017). In addition, this emotional response may be understood under the frame of cognitive dissonance, a psychological theory that explains the effect of mental discomfort when an individual is faced with information that conflicts with previous ideas. This theory is based on the assumption that persons seek to avoid the deception induced by the failure of their expectations (Festinger & Carlsmith, 1959) and has been incorporated into models of basic processes of learning (Guzzetti, Snyder, Glass, & Gamas, 1993). This is likely the explanation underlying the effectiveness of this approach to describe "difficult" wines to consumers in few tasting sessions (Loureiro et al., 2016). By comparing two very different wines, one initially more attractive which turns to be a deception and another that becomes a surprise, individuals may rapidly overcome this inconsistency when wine characteristics are explained based on climate/terroir influence. Another detail is the choice of wine examples. By tasting blind wines of undisputed quality (e.g. Pinot Noir from Burgundy), but which are not as appreciated as the gold medal awarded wines, the "surprise" effect is much more effective when wine identity is revealed given that expectations elicited by quality cues or extrinsic attributes influence sensory experience and consumer preference (De Pelsmaeker et al., 2017; Siegrist & Cousin, 2009). The objective was not to change wine liking, but in this study consumers rapidly expanded their understanding of quality range and are more prone to accept "difficult" wines. The emotional responses described in this work should be further explored to understand consumer behavior towards the effect of technological options like sugar addition (e.g. German Rieslings), carbonation (e.g. sparkling wines) or increase fruity/flowery flavors (e.g. fermentation at low temperature), thereby helping winemakers to fine tune wine sensory features.

5. Conclusions

The results presented herein show the great potential of emotional attributes to describe and differentiate wines. The novelty of this approach lies in the relationship between emotional descriptors elicited by wines and their sensory characteristics. The proposed method is more accessible to untrained subjects, yet allowed the evaluation and differentiation of wines. The combination of traditional technical descriptions with emotional responses may be easily used by wine professionals to raise awareness and educate consumers on different or more complex wines which do not necessarily fit the international style, such as those consistent with cool climate wines.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodres.2017.12.039.

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References

Bastian, S., Bruwer, J., & Alant, K. (2005). Wine consumers and makers: Are they speaking the same language? *Australian and New Zealand Grapegrower and Winemaker, 496*, 80–84.

Bruzzone, F., Vidal, L., Antúnez, L., Giménez, A., Deliza, R., & Ares, G. (2015). Comparison of intensity scales and CATA questions in new product development: Sensory charcaterisation and directions for product reformulation of milk desserts. *Food Quality and Preference, 44*, 183–193.

Cardello, M. H. A. B., & Faria, J. B. (1998). Análise descritiva quantitativa da aguardente de cana durante o envelhecimento em tonel de carvalho (*Quercus alba* L.). *Food Science and Technology, 18*, 169–175.

Cicchetti, D. V., & Cicchetti, A. (2009). Wine rating scales: Assessing their utility for producers, consumers, and enologic researchers. *International Journal of Wine Research, 1*, 73–83.

De Pelsmaeker, Schouteten, J., Lagast, S., Dewettinck, K., & Gellynck, X. (2017). Is taste the key driver for consumer preference? A conjoint analysis study. *Food Quality and Preference, 62*, 323–331.

Desmet, P., & Schifferstein, H. (2008). Sources of positive and negative emotions in food experience. *Appetite, 50*, 290–301.

Ferrarini, R., Carbognin, C., Casarotti, E. M., Nicolis, E., Nencini, A., & Meneghini, A. M. (2010). The emotional response to wine consumption. *Food Quality and Preference, 21*, 720–725.

Festinger, L., & Carlsmith, J. M. (1959). Cognitive consequences of forced compliance. *Journal of Abnormal and Social Psychology, 58*, 203–210.

Francis, I., & Williamson, P. (2015). Application of consumer sensory science in wine research. *Australian Journal of Grape and Wine Research, 21*, 554–567 (Frontiers in Integrative Neuroscience, 8, 1-8).

Guzzetti, B. J., Snyder, T. E., Glass, G. V., & Gamas, W. S. (1993). Promoting conceptual change in science: A comparative meta-analysis of instructional interventions from reading education and science education. *Reading Research Quarterly, 28*, 116–159.

Hedderley, D., & Wakeling, I. (1995). A comparison of imputation techniques for preference mapping using a Monte Carlo simulation. *Food Quality and Preference, 6*, 281–298.

Hayes, J. E., & Pickering, G. J. (2012). Wine expertise predicts taste and phenotype. *American Journal of Enology and Viticulture, 63*, 80–84.

Herz, R. S. (2000). Verbal coding in olfactory versus non-olfactory cognition. *Memory and Cognition, 28*, 957–964.

Hopfer, H., & Heymann, H. (2014). Judging wine quality: Do we need experts, consumers or trained panelists? *Food Quality and Preference, 32*, 221–233.

ISO 5492 (2008). *Sensory analysis. Vocabulary.* Geneva, Switzerland: International Organization for Standardization. https://www.iso.org/obp/ui/#iso:std:iso:5492:ed-2:v1:en.

Jackson, R. (2014). Sensory perception and wine assessment. In R. Jackson (Ed.). *Wine science, principles and applications* (pp. 831–888). London: Academic Press Inc.

Jager, G., Schlich, P., Tijssen, I., Yao, J., Visalli, M., de Graaf, C., & Stieger, M. (2014). Temporal dominance of emotions: Measuring dynamics of food-related emotions during consumption. *Food Quality and Preference, 37*, 87–99.

Jiang, Y., King, J., & Prinyawiwatkul, W. (2014). A review of measurement and relationships between food, eating behavior and emotion. *Trends in Food Science & Technology, 36*, 15–28.

Jinks, A., & Laing, D. G. (2001). The analysis of odor mixtures by humans: Evidence for a configurational process. *Physiology & Behavior, 72*, 51–63.

Kenney, E., & Adhikari, K. (2016). Recent developments in identifying and quantifying emotions during food consumption. *Journal of the Science of Food and Agriculture, 96*, 3627–3630.

King, S., Meiselman, H., & Carr, B. (2013). Measuring emotions associated with foods: Important elements of questionnaire and test design. *Food Quality and Preference, 28*, 8–16.

Lagast, S., De Steur, H., Schouteten, J., & Gellynck, X. (2017). A comparison of two low-calorie sweetners and sugar in dark chocolate on sensory attributes and emotional conceptualisations. *International Journal of Food Sciences and Nutrition*. http://dx.doi.org/10.1080/09637486.2017.1362689.

Langlois, J., Dacremont, C., Peyron, D., & Valentin, D. (2011). Lexicon and types of discourse in wine expertise: The case of vin de garde. *Food Quality and Preference, 2*, 491–498.

Lawless, H. (1999). Descriptive analysis of complex odors: Reality, model or illusion? *Food Quality and Preference, 10*, 325–332.

Livermore, A., & Laing, D. G. (1998). The influence of odor type on the discrimination and identification of odorants within multicomponent odor mixtures. *Physiology & Behavior, 65*, 311–320.

Lorig, T. S. (1999). On the similarity of odor and language perception. *Neuroscience & Biobehavioral Reviews, 23*, 391–398.

Loureiro, V., Brasil, R., & Malfeito-Ferreira, M. (2016). A new wine tasting approach based on emotional responses to rapidly recognise classic European wine styles. *Beverages, 2*, 1–17.

McMahon, K. M., Culver, C., & Ross, C. F. (2017). The production and consumer perception of sparkling wines of different carbonation levels. *Journal of Wine Research, 28*, 123–134.

Meilgaard, M. C., Carr, B. T., & Civille, G. V. (2006). *Sensory evaluation techniques* (4th ed.). Boca Raton: CRC.

Meiselman, H. L. (2015). A review of the current state of emotion research in product development. *Food Research International, 76*, 192–199.

Ng, M., Chaya, C., & Hort, J. (2013). Beyond liking: Comparing the measurement of emotional response using EsSense Profile and consumer defined check-all-that-apply methodologies. *Food Quality and Preference, 28*, 193–205.

Noble, A. C., Arnold, R. A., Masuda, B. M., Pecore, S. D., Schmidt, J. O., & Stern, P. M. (1984). The progress towards a standardized system of wine aroma terminology. *American Journal of Enology and Viticulture, 35*, 107–109.

Paradis, C., & Eeg-Olofsson, M. (2013). Describing sensory experience: The genre of wine reviews. *Metaphor and Symbol, 28*, 22–40.

Parr, W., Heatherbell, D., & White, G. (2002). Demystifying wine expertise: Olfactory threshold, perceptual skill and semantic memory in expert and novice wine judges. *Chemical Senses, 27*, 745–755.

Picard, M., Tempere, S., Revel, G., & Marchand, S. (2015). A sensory study of the ageing bouquet of red Bordeaux wines: A three-step approach for exploring a complex olfactory concept. *Food Quality and Preference, 42*, 110–122.

Rive, A., & Deneulin, P. (2014). Investigation of emotional expressions elicited by wine odor. *Eurosense – 6th European conference on sensory and consumer research, 7–10*

September. Copenhagen: Denmark.
Sáenz-Navajas, M. P., Avizcuri, J., Echávarri, J., Ferreira, V., Fernández-Zurbano, P., & Valentin, D. (2016). Understanding quality judgements of red wines by experts: Effect of evaluation condition. *Food Quality and Preference, 48*, 216–227.
Sáenz-Navajas, M. P., Ballester, J., Pêcher, C., Peyron, D., & Valentin, D. (2013). Sensory drivers of intrinsic quality of red wines, Effect of culture and level of expertise. *Food Research International, 54*, 1506–1518.
Sáenz-Navajas, M. P., González-Hernández, M., Campo, E., & Fernández-Zurbano & Ferreira, V. (2012). Orthonasal aroma characteristics of Spanish red wines from different price categories and their relationship to expert quality judgements. *Australian Journal of Grape and Wine Research, 18*, 268–279.
Samant, S., Chapko, M., & Seo, H.-S. (2017). Predicting consumer liking and preference based on emotional responses and sensory perception: A study with basic taste solutions. *Food Research International, 100*, 325–334.
Siegrist, M., & Cousin, M.-E. (2009). Expectations influence sensory experience in a wine tasting. *Appetite, 52*, 762–765.
Silva, R., Minim, V., Simiqueli, A., Moraes, L., Gomide, A., & Minim, L. (2012). Optimized descriptive profile: A rapid methodology for sensory description. *Food Quality and Preference, 24*, 190–200.
Stone, H., & Sidel, J. L. (2004). *Sensory evaluation practices* (3rd ed.). New York: Academic Press.
This, P., Lacombe, T., & Thomas, M. R. (2006). Historical origins and genetic diversity of wine grapes. *Trends in Genetics, 22*, 511–519.
Thomson, D., Crocker, C., & Marketo, C. (2010). Linking sensory characteristics to emotions: An example using dark chocolate. *Food Quality and Preference, 21*, 1117–1125.
Ubigli, M. (2004). *I profili del vino: alla scoperta dell'analisi sensoriale.* Bologna: Edagricole.